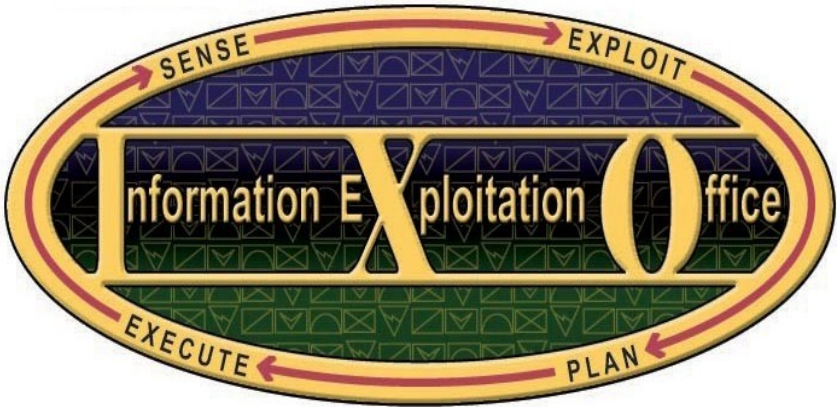
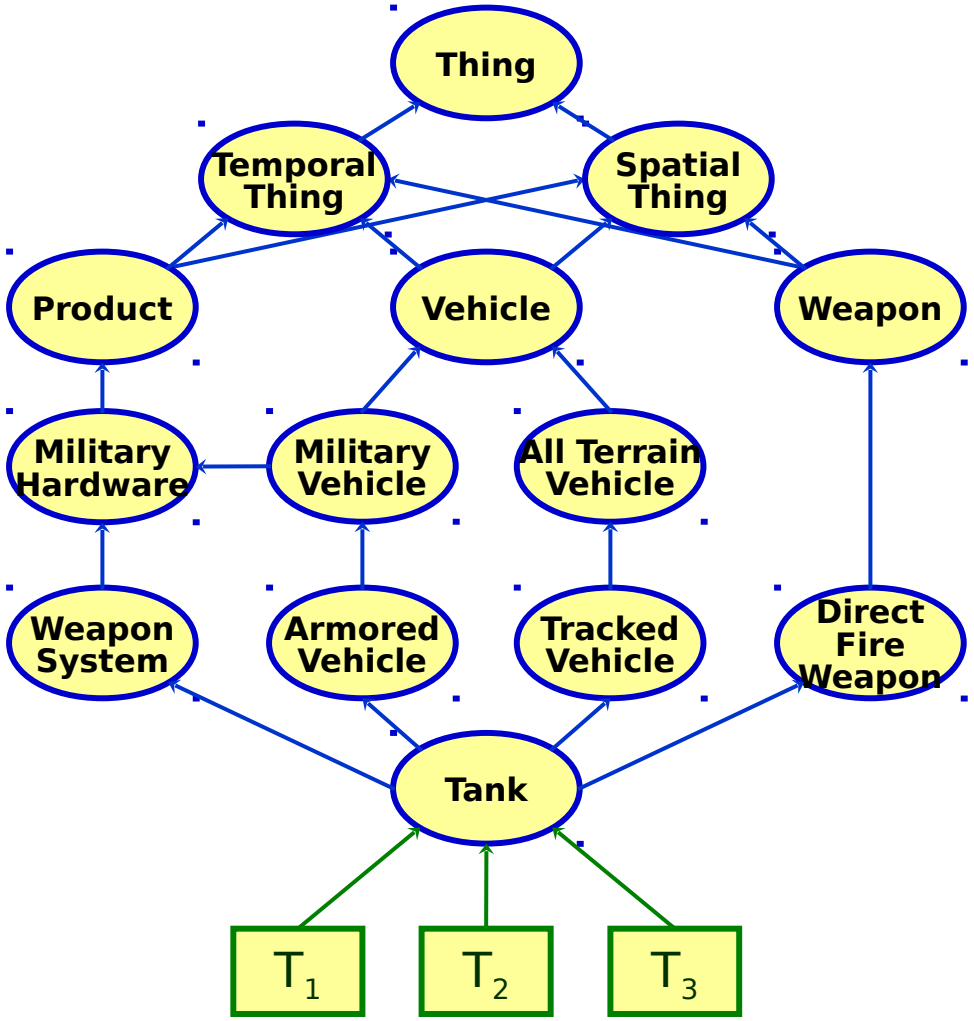


Rapid Knowledge Formation (RKF)

Technology to enable military experts to author, share, and reuse C²I knowledge bases

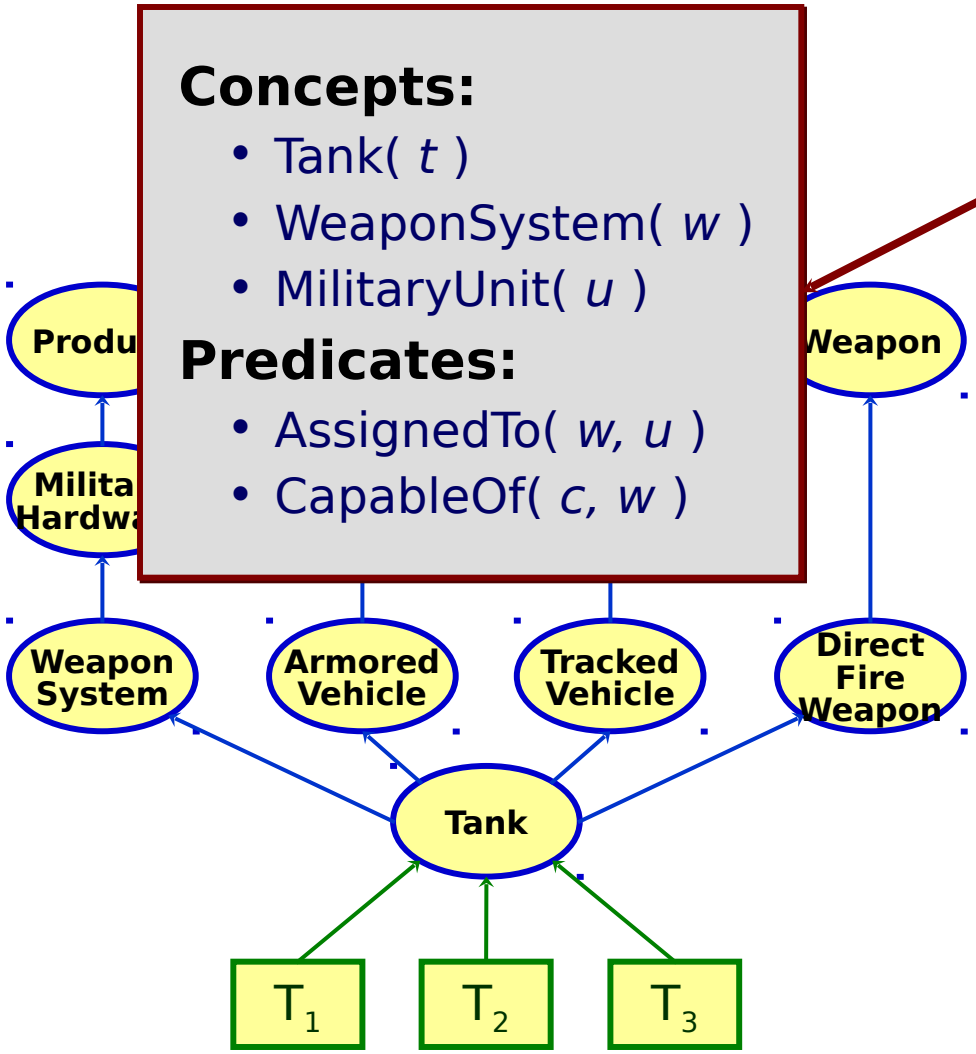
Murray Burke
IXO

What do we mean by knowledge?



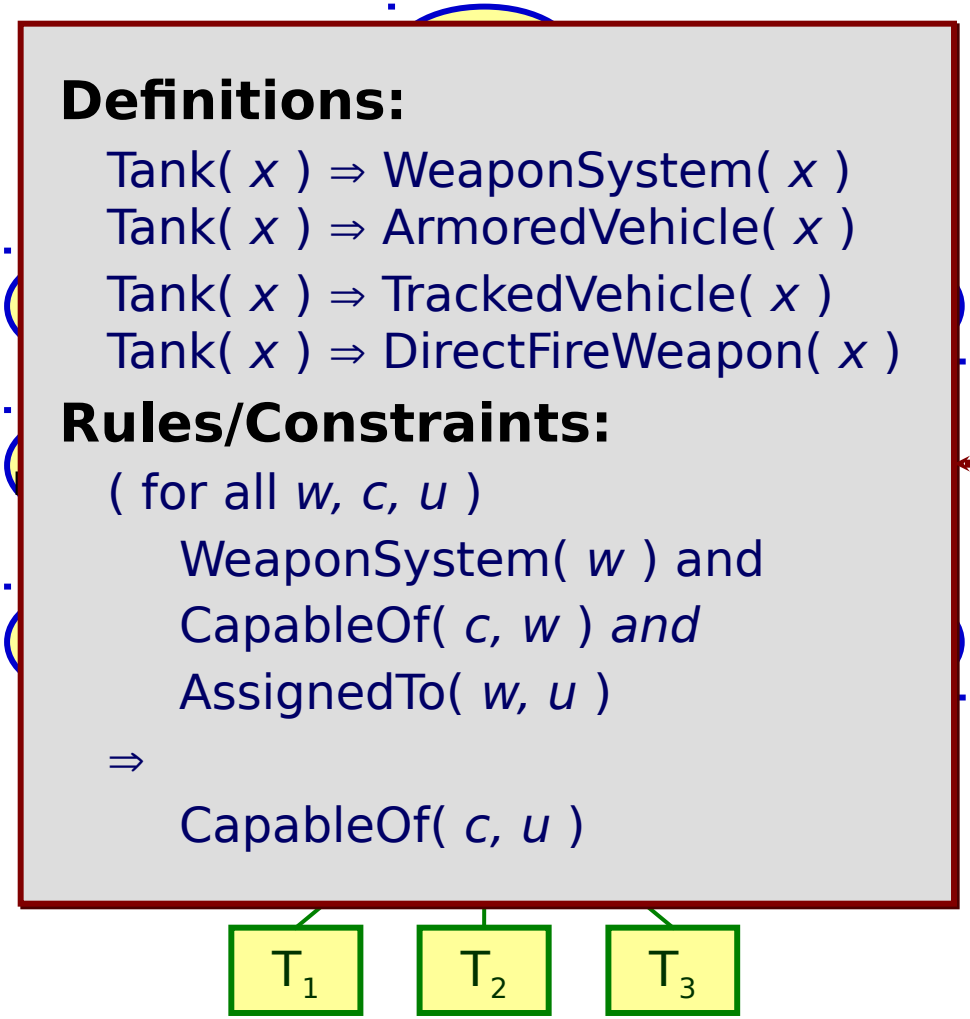
- **Vocabulary**
  - Concepts (Types)
  - Predicates (Relations)
- **Axioms**
  - Definitions
  - Rules
  - Constraints
- **Data**
  - Instances of Concepts
  - Instances of Predicates

What do we mean by knowledge?



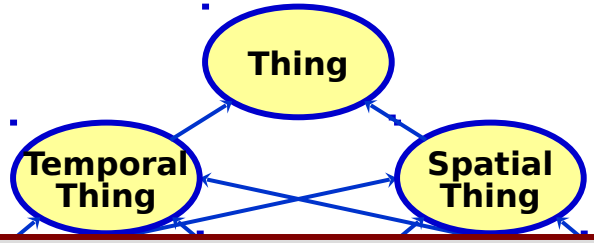
- **Vocabulary**
  - **Concepts (Types)**
  - **Predicates (Relations)**
- **Axioms**
  - Definitions
  - Rules
  - Constraints
- **Data**
  - Instances of Concepts
  - Instances of Predicates

What do we mean by knowledge?



- **Vocabulary**
  - Concepts (Types)
  - Predicates (Relations)
- **Axioms**
  - **Definitions**
  - **Rules**
  - **Constraints**
- **Data**
  - Instances of Concepts
  - Instances of Predicates

What do we mean by knowledge?



Instances of Concepts:

Tank(T_1)

Tank(T_2)

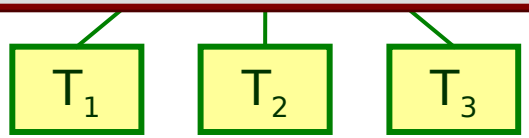
Tank(T_3)

Instances of Predicates:

AssignedTo(T_1, 21^{st}*ArmoredBrigade*)

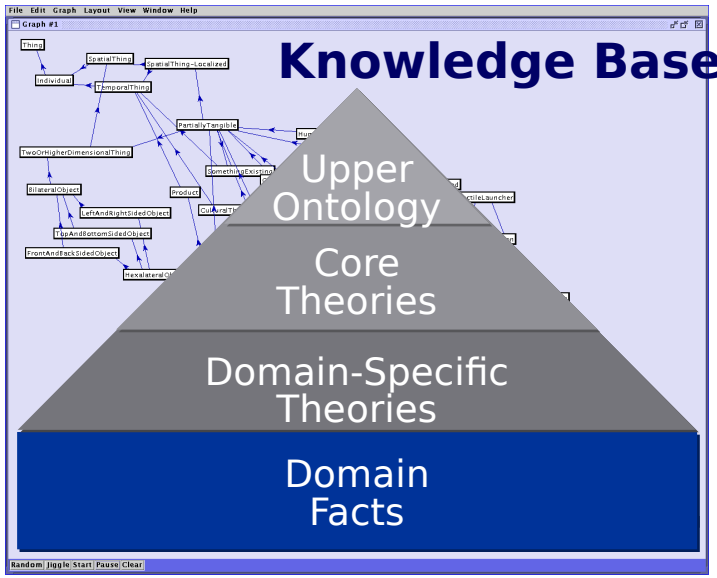
AssignedTo(T_2, 21^{st}*ArmoredBrigade*)

AssignedTo(T_3, 21^{st}*ArmoredBrigade*)



- **Vocabulary**
  - Concepts (Types)
  - Predicates (Relations)
- **Axioms**
  - Definitions
  - Rules
  - Constraints
- **Data**
  - **Instances of Concepts**
  - **Instances of Predicates**

What is knowledge good for?



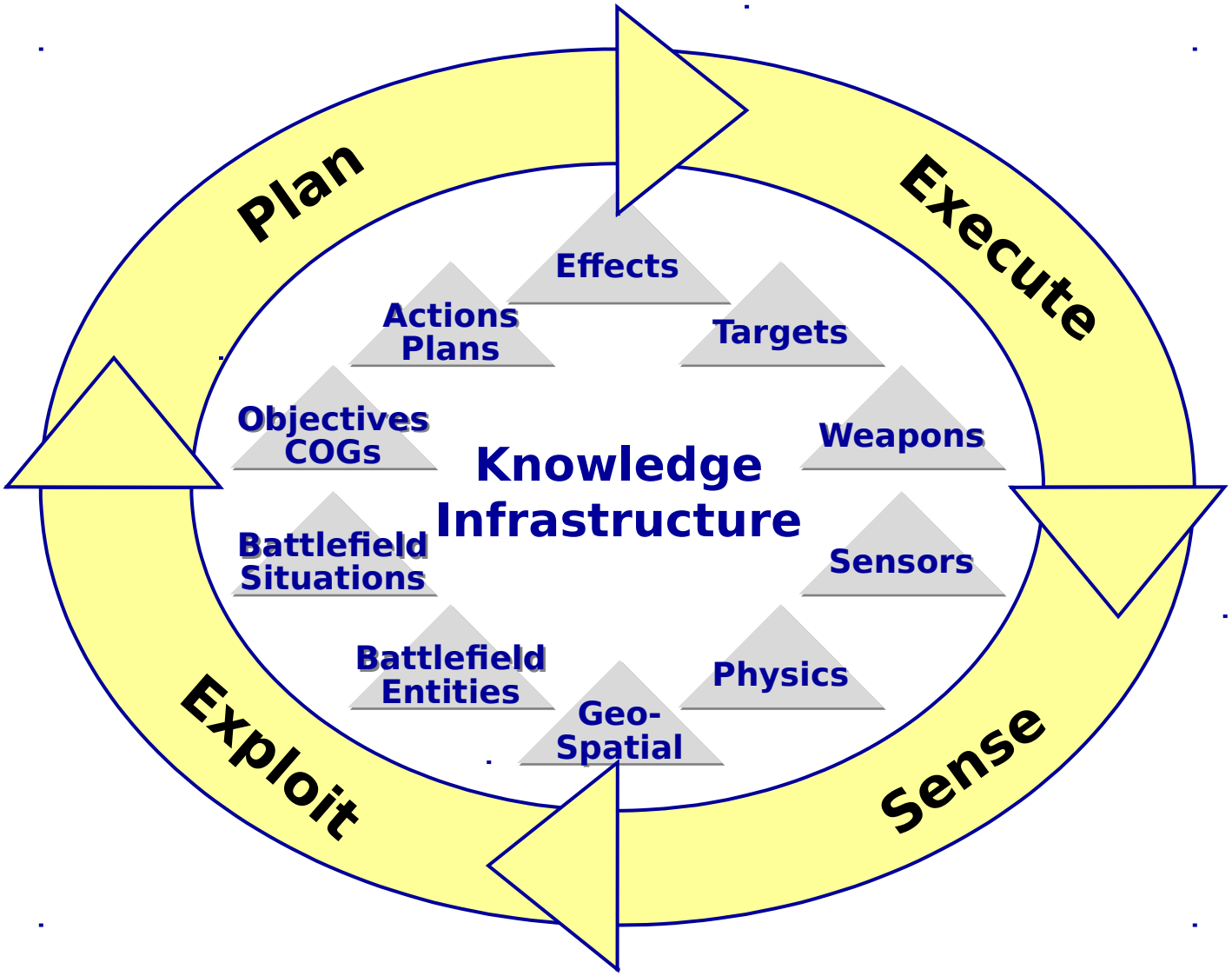
T_1 is a Tank

From 1 datum

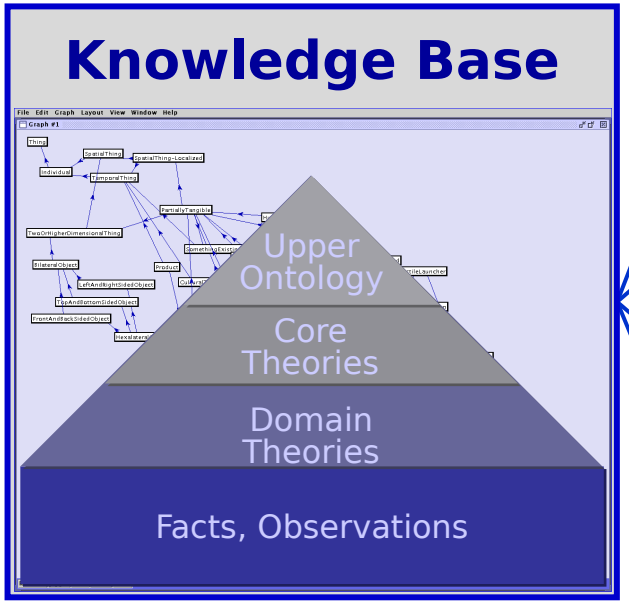
- **T_1 moves on the land**
- **T_1 needs a trained driver**
- **T_1 leaves tracks**
- **T_1 has armor protection**
- **T_1 is made of metal**
- **T_1 can cross rivers**
- **T_1 can destroy targets in range**
- **T_1 requires power**
- **T_1 can be bought and sold**
- **T_1 exists in one location only**
- **T_1 occupies space**
- **T_1 exists in time**
- **T_1 …**

We can infer many things

Knowledge is Needed for IXO Applications



What is battlespace knowledge good for?



- Objectives Editor
- Planner
- Effects Simulator
- Fusion Engine (L2/3)

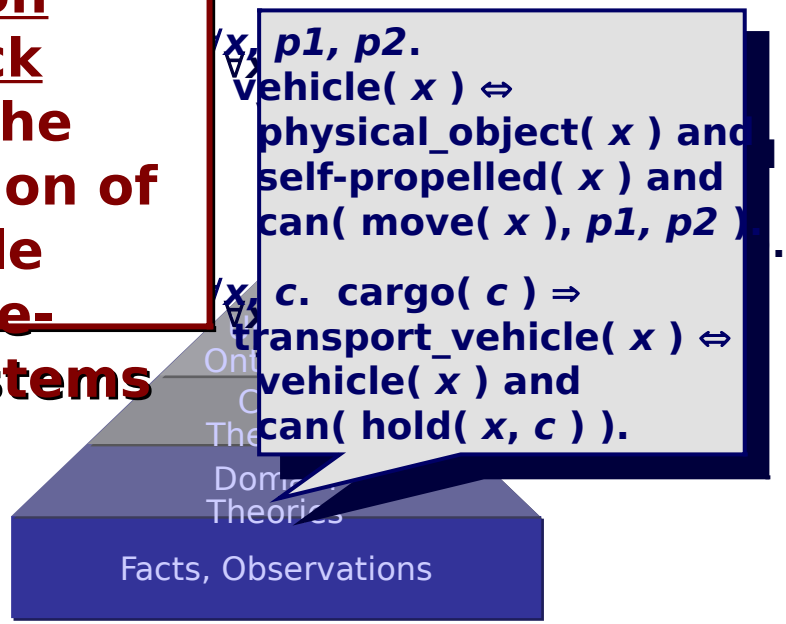
- Enables the commander or staff to input and edit their objectives.
- Translates the objectives into plans and generates alternatives.
- Simulates planned actions to check for intended and unintended effects.
- Uses background knowledge to fuse sensor and other information.

What's Hard in RKF

Human Knowledge

The Knowledge Acquisition Bottleneck prevents the implementation of large scale knowledge-intensive systems

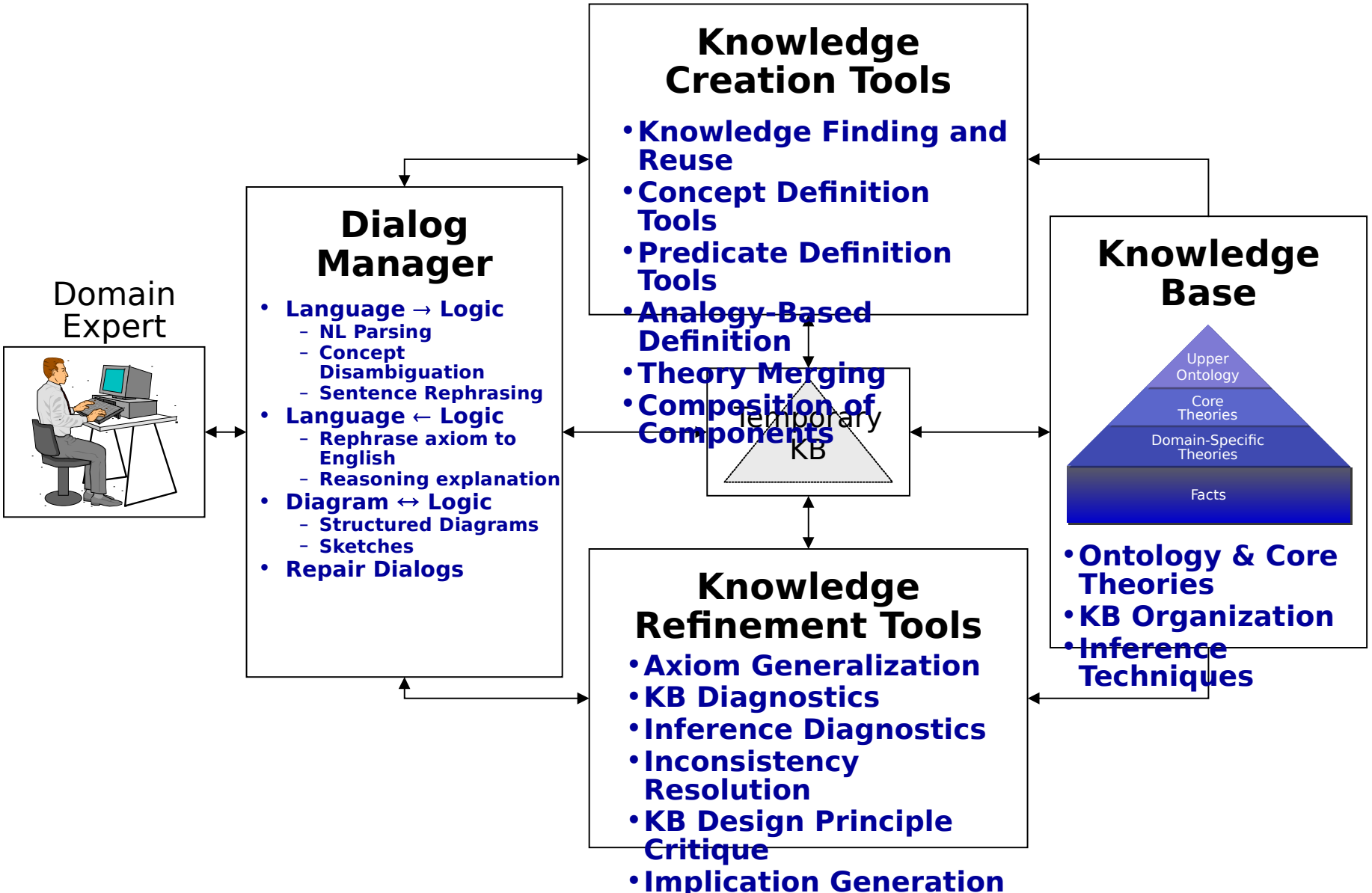
Machine Knowledge



- Natural Language
- Reasoning by Analogy
- Image-Based
- Built-in Spatial Reasoning
- "Common Sense"

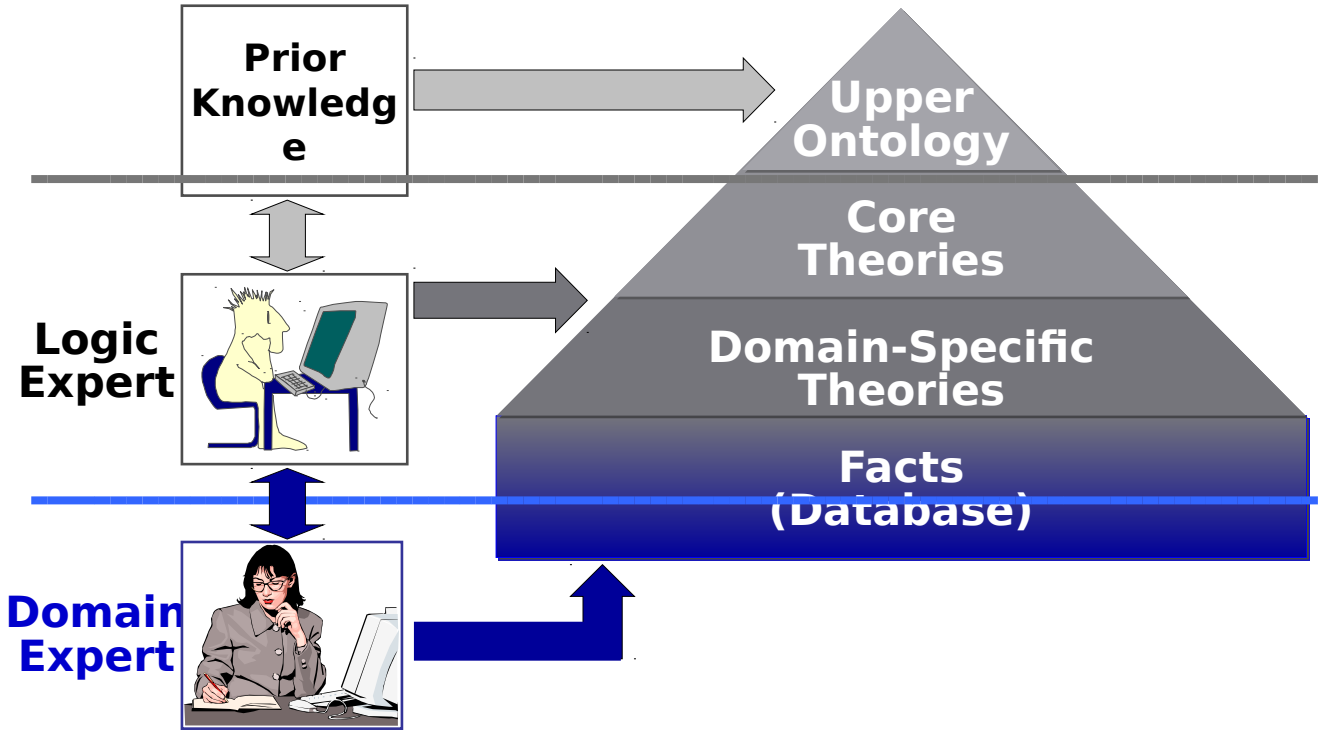
- Formal Mathematical Language
- Logical Deduction, Inference
- Symbol-Based
- Explicitly Defined Knowledge
- Missing "Common Sense"

RKF Functional Architecture



Building a Formal Knowledge Base

(State of the Art – 1998)



1. Begin with a large, reusable ontology.
2. Logic experts extend the KB to create:
   - core theories
   - domain theories
   - initial domain facts
3. Domain experts fill in some domain facts.

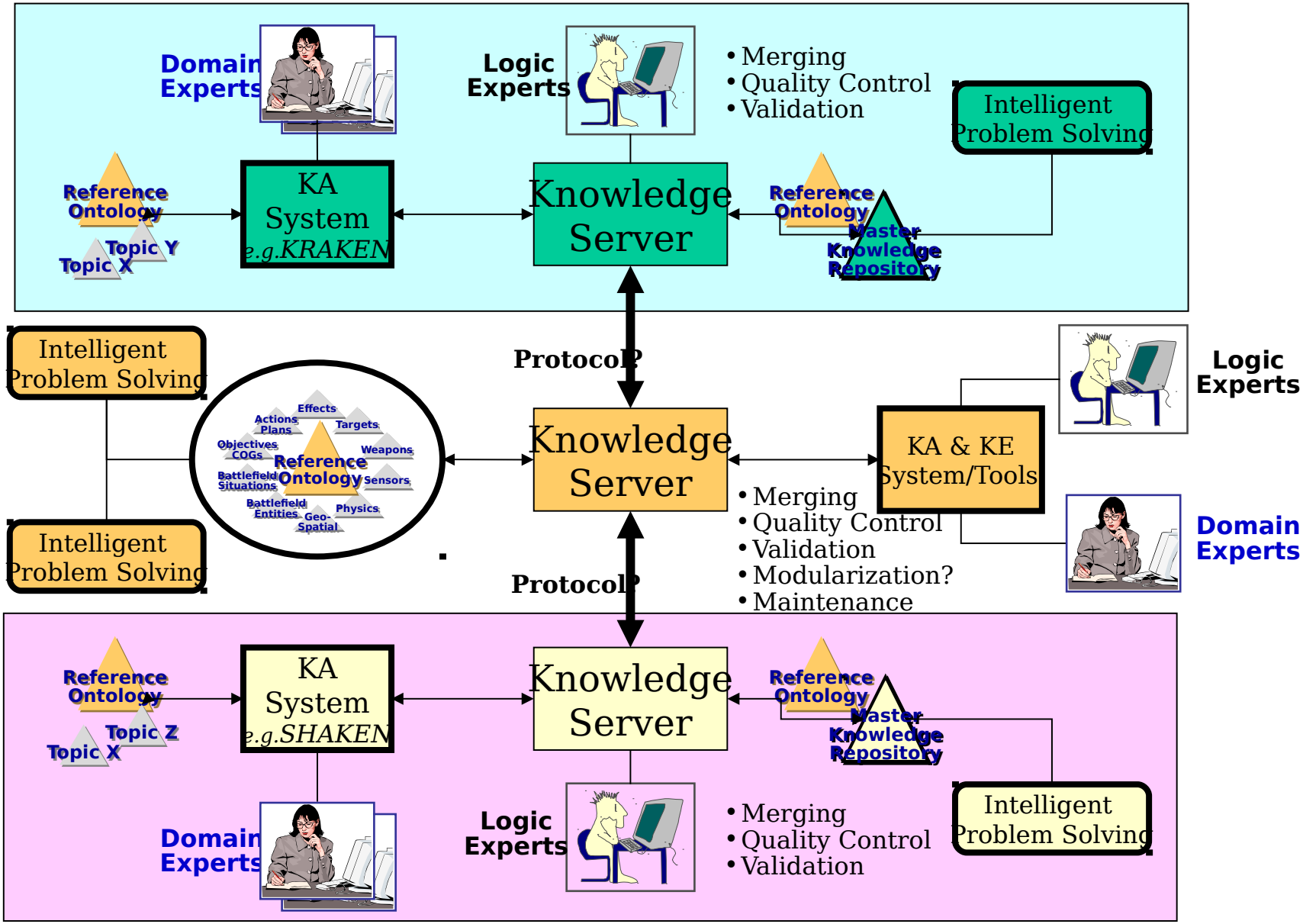
At the start of RKF, a Logic Expert could enter knowledge at an average rate of 5 axioms per hour.

⇒

A team of 10 Logic Experts could build large (100,000 axiom) KB in 12 months.

RKF Goal for 2003

Cooperative Large Scale Battlespace KBs



RKF Program Organization

ndependent
Evaluation

Challenge Problem

IET

ntegratio
Teams

Technolog
Developer

Cycorp

Uses a large (million axiom), context organized, KB, with a full NL Dialog system for knowledge entry.

Creation
Cycorp
NWU
GMU

Dialog
Cycorp
Teknowledge
SAIC

Temporary KB

KB
Cycorp,
Edinburgh U

Refinement
USC / ISI
Stanford KSL

SRI

Uses a novel approach to create knowledge by composing generic components, via diagram entry.

Creation
SRI
NWU
U.T. Austin

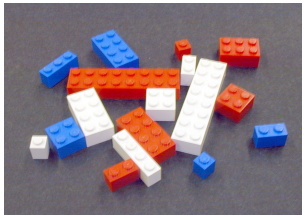
Dialog
MIT
U. W. FL
Boeing
USC / ISI

Temporary KB

KB
SRI,
U.W.Fl.,
U.T. Austin,
U. MASS,
PSR

Refinement
U. Mass
Stanford KSL/FRG
Pragati

RKF Team Comparison

	Cycorp 	SRI 
KB Organization	• MicroTheories • based on Truth Context • Existing KB size ≈1,000,000 axioms	• Generic Components • based on Functional Hierarchy • Anticipated KB size ≈100's to 1000's of components
Knowledge Creation Technique	• Knowledge creation by reusing and modifying axioms to extend KB w/ new predicates	• Knowledge creation based on a new logic operator for component composition
Knowledge Entry Dialogue	• Natural Language Dialogue • rephrase English into Logic • based on extensive lexicon of terms in	• Concept Maps (pictorial) • Tools • entry dialogue to edit and combine component diagrams • limited Natural

RKF Comparative Evaluation

Textbook Challenge Problem:

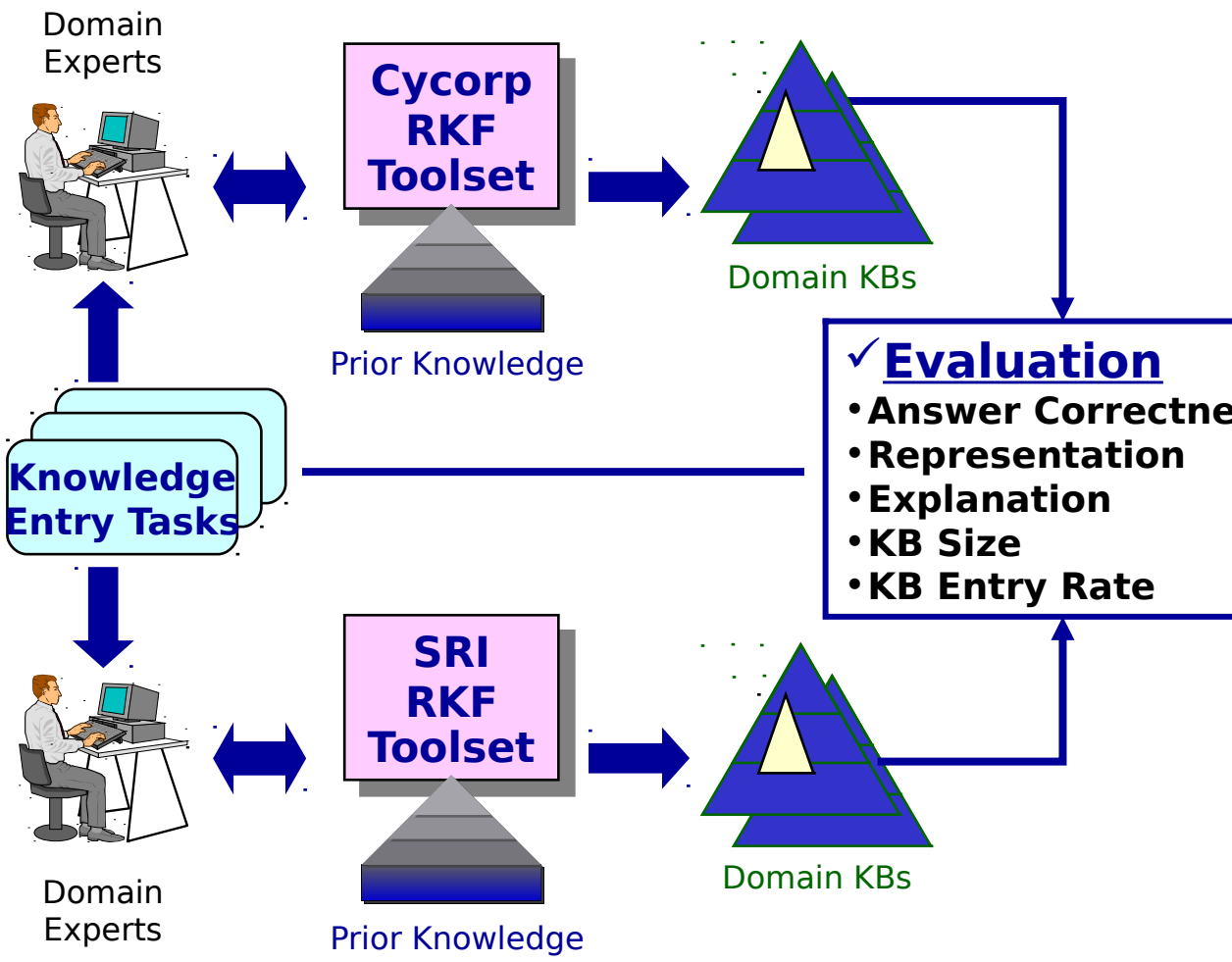
Encode sections from Chap 7, "DNA → RNA Transcription", from *Essential Cell Biology*, Alberts, et. al.

Subjects:

The domain experts were 8 graduate students in Biology from GMU.

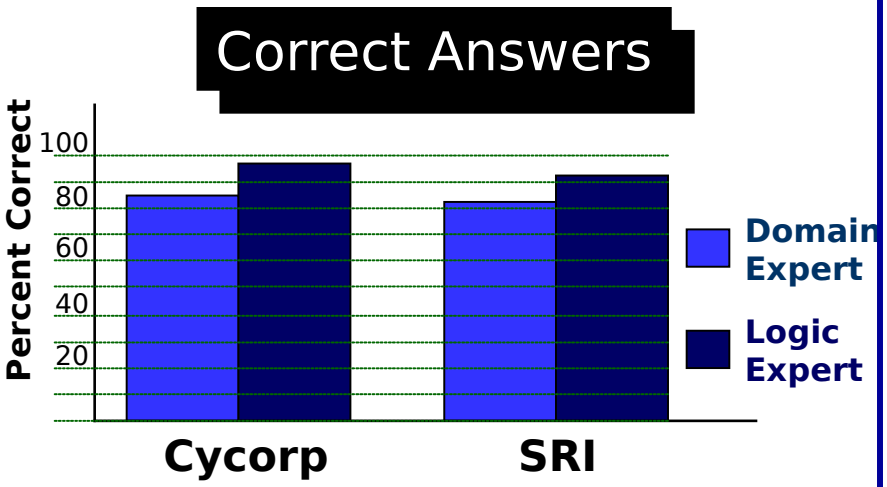
Test Procedure

- **Subjects were trained for 1 week on the RKF tools.**
- **Subjects spent 4 weeks entering textbook knowledge from 5 sections (with controlled access to logic experts).**
- **Subjects posed quiz-level**

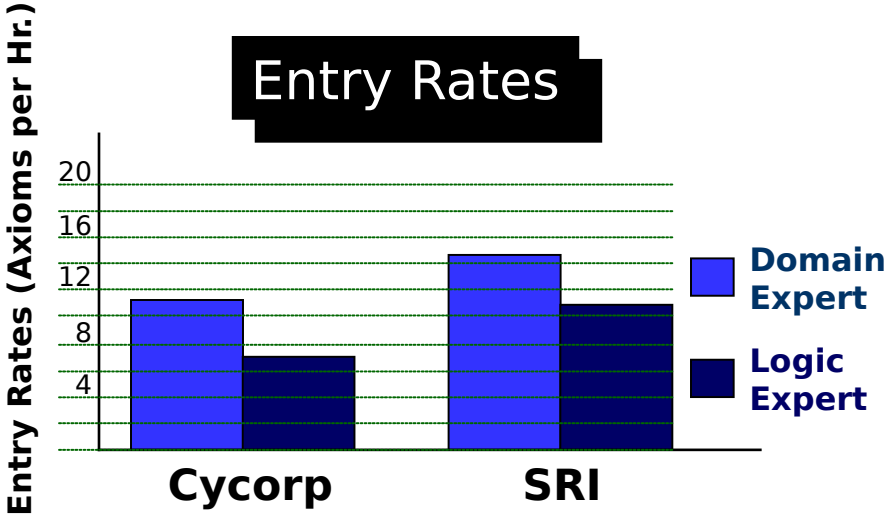


Logic Experts from each team also performed the knowledge entry tasks, as a baseline reference.

Initial RKF Evaluation, Summer 2002



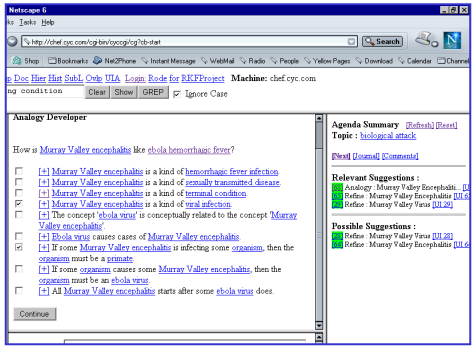
- Logic Experts' KBs got A's
- Domain Experts' KBs got B's and C's (but passed!)
- Logic Experts had much better understanding of the ontologies, tools, and knowledge entry tasks.



- Domain Experts' entry rates comparable to Logic Experts':
  - 10-15 axioms per hour
- Logic Experts entered fewer, but more complex axioms.
  - 5-10 axioms per hour

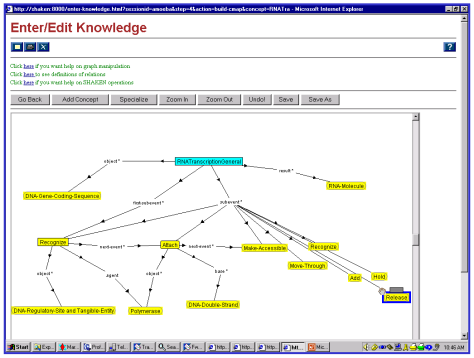
RKF Assessment After Initial Evaluation

Cycorp



- Positive
  - Handled complex expressions
  - Easy creation of instances and concepts
  - NL processing of noun phrases worked well
- Negative
  - Complex features were difficult to understand
  - “Buggy” modules prevented NL entry of full sentences

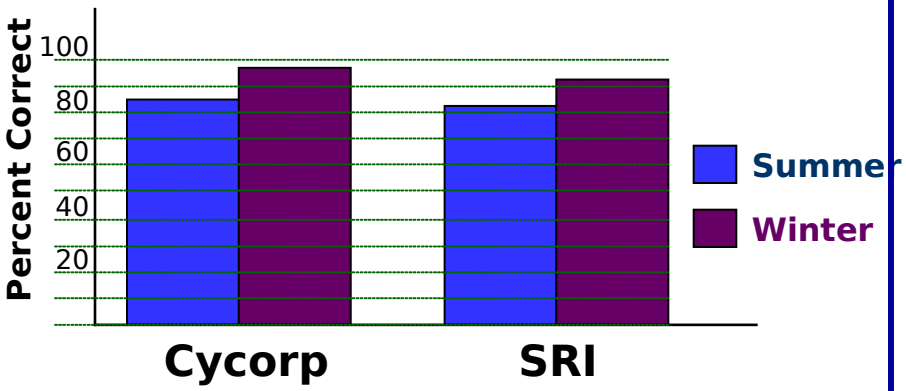
SRI



- Positive
  - Easy for user’s to understand
  - Graphical entry worked well for creating components
  - Small component library easy to navigate
- Negative
  - Limited expressive power
  - Users could not enter many complex concepts

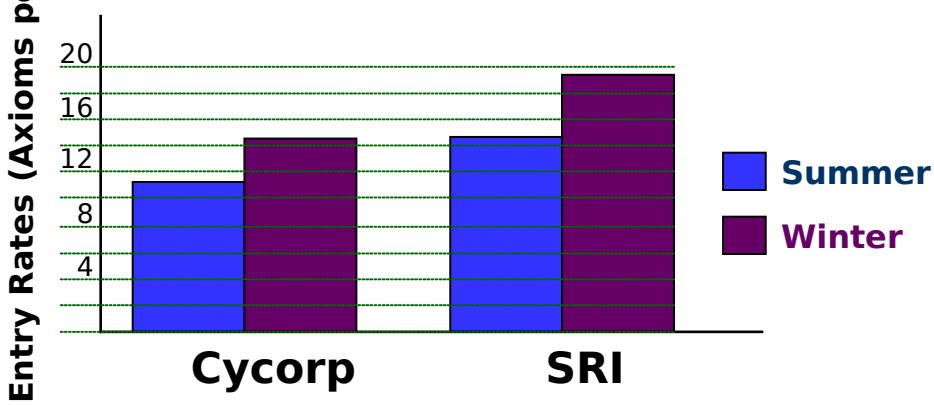
RKF 6-Month Retest, Winter 2002

Higher Scores (Domain Experts)



- Domain experts' KBs got A's
  - Domain Experts caught up with the Logic Experts
- Higher quality KBs created.
- Interesting system differences
  - SRI stronger at initial entry
  - Cycorp stronger at refinement

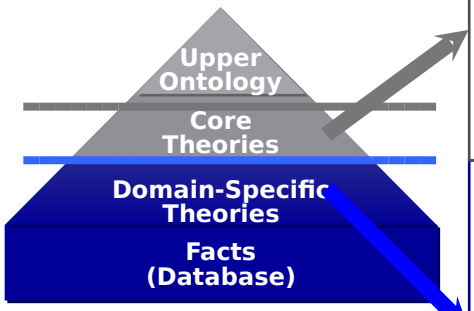
Faster Entry (Domain Experts)



- Entry rates for domain experts increased significantly.
- Improved tools, like analogy, rapidly created new axioms.
- Improved tools led user through more complex entry sequences.

RKF Performance by Knowledge Entry Task

Original Goal



Knowledge Entry Task: EnterFinalize

Core Theories	Predicates		
	Rules		
	Concepts		
Domain Theories	Predicates		
	Rules		
	Concepts		
	Instances		

Projected Total Effort

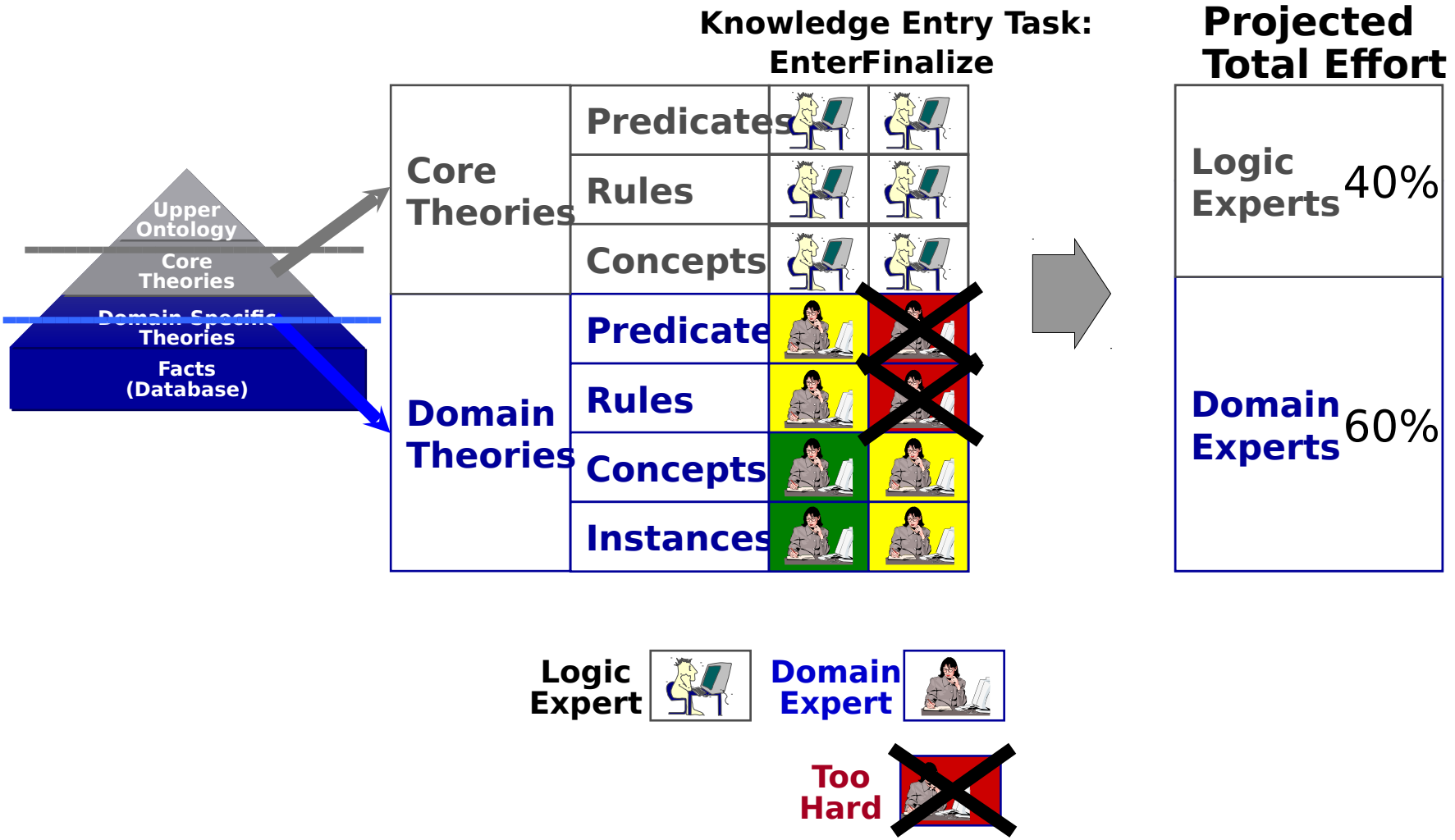
Logic Experts	20%
Domain Experts	80%

Logic Expert 

Domain Expert 

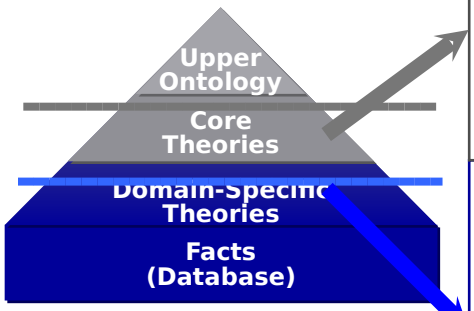
RKF Performance by Knowledge Entry Task

FY 01 Results



RKF Performance by Knowledge Entry Task

New Goal



Knowledge Entry Task: EnterFinalize

Core Theories	Predicates		
	Rules		
	Concepts		
Domain Theories	Predicates		
	Rules		
	Concepts		
	Instances		

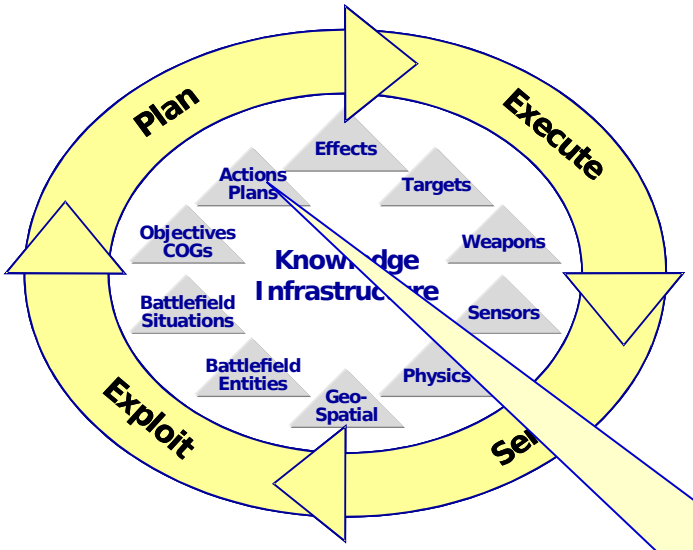
Projected Total Effort

Logic Experts	30%
Domain Experts	70%

Logic Expert 

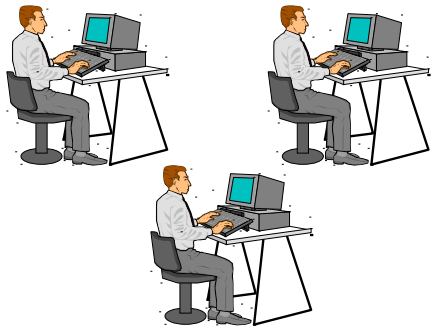
Domain Expert 

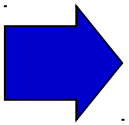
RKF FY02 Challenge Problem: Authoring Battlefield Knowledge

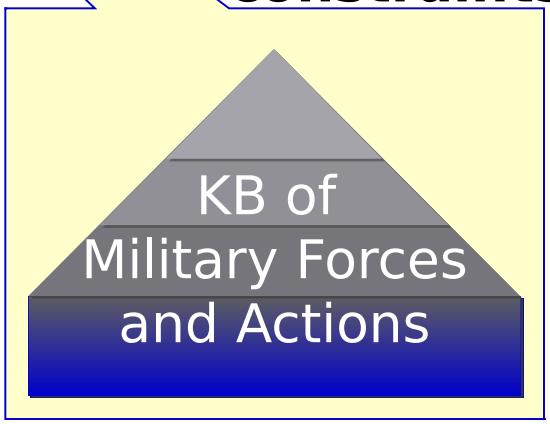


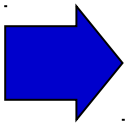
- **Military Domain Experts will author knowledge of military forces and activities, involving time-critical targets and terrain**
- **The knowledge will be used to PBA analysis based on situation constraints**

Military Domain Experts





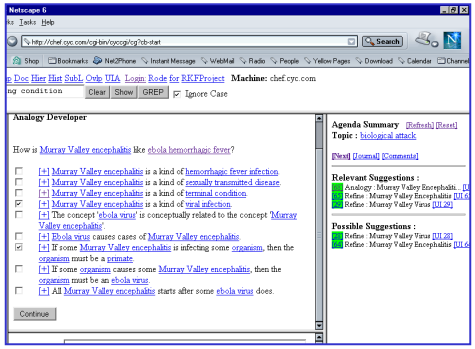




Predictive Battlespace Awareness (PBA) Module

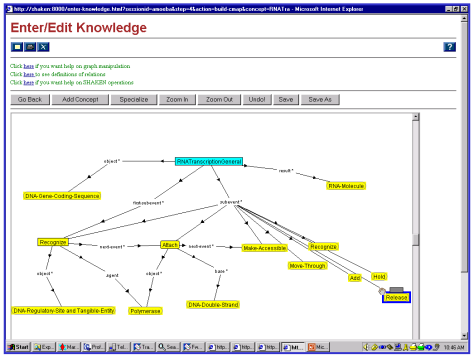
RKF Development Plans for 2003

Cycorp



- **Knowledge Driven Dialogs**
  - **Using existing knowledge**
  - **Using Knowledge-entry knowledge**
  - **Reasoning about the knowledge entry and learning process**
- **Scripts and Planning**
  - **Richer representation of actions, plans**
  - **Improved entry tools for describing actions, processes**
- **Analogy formation**
- **Query Failure Diagnosis**

SRI



- **Improved Graphical Entry**
  - **Entering aggregate components**
- **Expanded Axiom Classes**
  - **Richer expression language**
- **New Process Language & Simulator**
- **Improved Diagnostics**
- **Improved Dialog Management**
  - **Enhanced Explanation**
  - **Enhanced Query**

RKF Accomplishments

1. Built two knowledge-base authoring systems
2. Sent the systems “to school” to learn biology (FY01)
   - Grad students in Biology “taught” the systems “Biology 101”
3. Tested the authored knowledge-bases (KBs)
   - Tested KBs for question-answering competence
   - Learned strengths and weaknesses of each approach
   - Re-built the systems based on lessons learned
   - Re-tested the systems in a 6 month re-test
4. Got some good press
   - PBS, Scientific American, MIT Tech Review, LA Times
5. Facilitated transitions to military customers

Cycorp RKF System (Cyc) in the News

PBS Documentary: ***2001: Hal's Legacy***

"Cyc is programmed to ask questions about every sentence until it gets the context and, at a simple level, the meaning."

– April November 27, 2001

Scientific American: ***The World in a Box***

"Watching Cyc at work with a prototype natural-language interface is like watching a chat-room session with a tirelessly polite but ruthlessly inquisitive version of Helen Keller."

– January, 2002

MIT Technology Review: ***A.I. Reboots***

– March, 2002

". . . The system came tantalizingly close to that crossover state in which it knew what it did not know and sought, without being prompted, to fill those gaps on its own."

LA Times: ***The Birth of a Thinking Machine***

– June 21, 2001

"Cycorp's staff engages in a dialogue day and night with their unremittingly curious electronic colleague."

RKF Transitions

US Strategic Command

Information Network Vulnerability Analysis

KB system reasons about network vulnerabilities, check for IAVA compliance.

US Army War College

Center of Gravity Analysis

RKF Component used for COG Training

RKF PI became Chair of AI for War College

US Army CECOM

Agile Commander ATD

***DaVinci* (Courses of Action Tool)**

USAF Rome Laboratory

***Theater Ballistic Missile Tracking* (SBIR)**